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Early interactions between orienting, visual sampling and decision making in facial preference

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Abstract

Decision making has been regarded as the last stage before action in the human information processing, certainly subsequent to sensory sampling and perceptual integration. Our latest study showed that orienting contributes to preference decision making, by integrating preferential looking and mere exposure in a positive feedback loop leading to the conscious choice. Here, we introduce a gaze-contingent window method of stimulus presentation into our experimental paradigm, to completely block holistic stimulus processing while preserving piecemeal sampling through the gaze-contingent "peephole". This effectively zooms the visual processing in time domain, allowing us to show that orienting and decision making can interact long before the actual conscious choice. The finding also suggests that this interaction is independent of holistic properties of face stimuli and can be totally memory-driven.

Keywords: Eye-movements; Gaze; Preference; Decision making; Gaze-contingent displays; Face perception; Face attractiveness; Orienting behavior

1. Introduction

The orienting reflex is an automated redirection of attention towards an unexpected stimulus (Sokolov, 1963). Developed as a novelty detection mechanism, it provides the basis for the entire orienting behavior, whose components are no longer automatic and whose scope goes far beyond a fight-or-flight reaction. The behavior itself has recently been attributed active roles in high-level social as well as cognitive functions, such as mate selection (Hauser & Agnetta et al., 1998), recognition of emotions (Adolphs & Gosselin et al., 2005), and preference decision making (Shimojo & Simion et al., 2003). In many species, the mate selection ritual starts with orienting towards the potential partner, and in humans it is well known that gaze contact expresses interest or desire to collaborate (Emery, 2000; Kleinke, 1986). These examples depart from the classic view that orienting strictly equals attention focusing, but there is little experimental data indicating *how* orienting can participate in higher-level mental functions.

In a past study (Shimojo & Simion et al., 2003), we showed that gaze assists the brain in making a decision, especially in preference tasks. Specifically, we noticed that, while comparing two stimuli for attractiveness, observers' increasingly biased their gaze towards the eventual choice, the closer to the conscious decision they were. Moreover, we showed that manipulating gaze can influence observers' preference. A simple model linked orienting to decision making, using phenomena well-described in the literature: mere exposure effect (Kunstwilson & Zajonc, 1980; Zajonc, 1968), and preferential looking, (Fantz, 1964). Note that, in natural situations, active gaze shift can mediate both, so the more we look at a stimulus, the more we like it and the more we like it, the more we tend to look at it. The illustration of this positive feedback loop was a continually increasing gaze bias towards choice during preference tasks, which we called the "gaze cascade effect".

Thus, we proposed that orienting is not merely a means for gathering relevant information, but also as an active

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part of the decision process. Such assertion would suppose fast connections between gaze control areas (frontal eye fields, LIP, Shipp, 2004) and decision structures (prefrontal cortex, Fellows & Farah, 2005) or even face/object perception (inferior temporal cortex, Sigala & Logothetis, 2002) and memory (hippocampus, Corkin, 2002) areas, as well as feedback fibers gathering information necessary to update and control gaze position and duration.

In the present study, we introduced a new method of stimulus presentation in our experimental paradigm, which prevented holistic stimulus perception, while allowing piecemeal, feature perception. Specifically, subjects could inspect pairs of human faces through a small gaze-contingent window (‘‘peephole’’, Fig. 1) while they compared them for attractiveness or roundness. Gaze-contingent displays allow only a narrow foveal view, and have been extensively used (Rayner, 1998) in experiments involving reading (McConkie & Rayner, 1975), scene perception, visual search (Bertera & Rayner, 2000; Pomplun & Reingold et al., 2001; Saida & Ikeda, 1979), and even face recognition. Usually, these studies investigated the influence of perceptual span (controlled by the size of the window) on subjects' performance in the respective tasks. The general consensus is that smaller windows decrease either performance or reaction time, a result which we will treat as a given herein. Presenting the stimuli in this particular way in our study serves three purposes: (a) it makes the judgment (preference or control) more difficult, allowing analysis over a more extended period of time, (b) decouples orienting from diagnostic stimulus features that might act as attention grabbers, rendering its control to internal factors such as intention and memory and (c) eliminates the potential contribution of an initial holistic assessment of the entire stimulus to the preference decision.

With regard to (c) above, our initial demonstration (Shimojo & Simion et al., 2003) relied on the presence of

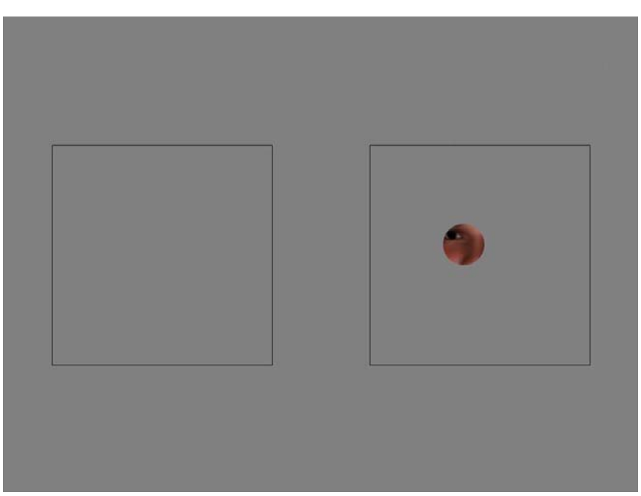

Fig. 1. An example of what observers could see through the gaze-contingent window. Note that only a small portion of the display is visible at any moment in time, although the general areas occupied by the faces are indicated through the rectangles to aid the observers in their search.

holistic visual stimuli. It was therefore unclear whether the connection between orienting and preference would still exist without it. Moreover, since we allowed subjects to choose the more attractive stimulus without imposing any restrictions, the average reaction time analyzed was around 3 s, of which only the last second represented the gaze bias effect. Thus, assessing how early in the visual processing the orienting behavior intervenes was difficult because of possible confounds, such as selection bias or stimulus-locking by gaze, all factors being jammed together in a small temporal window before the subject's response.

The difficulty of the tasks in the new setup would enable us to zoom the decision process in time domain, reassessing, with better temporal resolution, the contribution of orienting to preference formation while the whole stimulus is never shown, but sampling and integration of local visual information is on-going. If the gaze behavior bears similarities with what we observed in the full-stimulus tasks (i.e., the existence of a ‘‘cascade effect’’), we would consider it *direct* evidence of orienting as being embedded in the mechanism of preference decision making, since now the behavior would be entirely separated from its attention-grabbing purpose.

Finally, many studies make a distinction between the overt choice, expressed usually through a button press or verbal report, and the decision, which is assumed to be internal (Schall, 2001). However, in this study, we will follow the deployment of the orienting behavior and its connections to what *we* call the decision process, lasting from the stimulus onset to the moment of response.

2. Results

The stimuli used in this study consisted of pairs of computer-generated human faces (www.facegen.com), hidden behind a blank screen. Using Eyelink2© (www.eyelinkinfo.com) we defined a small, circular gaze-contingent window through which observers could inspect the display underneath, as if looking through a ‘‘peephole’’. The size of the window was set so that only one feature (e.g., eye, nose, mouth, and ear) of a face was visible at any point in time. Observers had to choose the more attractive face (main task) or the rounder face (control task).

Observers' gaze position was sampled and for each time t, we calculated the likelihood that gaze was directed to the face eventually chosen, as described in Shimojo and Simion et al., 2003 (see Section 4 for details). Average decision times were 35.1 ± 20.4 s for the attractiveness task and 29.3 ± 15.4 s for the roundness task. The last 14 s (approx. mean RT minus 1 standard deviation) were included in the gaze likelihood analysis. For comparison, we mention that in our previous study decision times were one order of magnitude shorter in the full-stimulus experiments (3–4 s) and only the last 2.5 s were included in the analysis. We view this difference between decision times as a ‘‘time lens’’ through which we can examine with better resolution the influence of gaze on preference formation.

Fig. 2 shows the likelihood curves for the current study, plotted against time until decision, in the preference (A) and roundness (B) tasks. A level close to 50% means that the two faces were equally probable to be inspected. Any consistent and significant abatement above this level illustrates a gaze bias towards choice. The curves are the average of $N = 7$ (A) or $N = 4$ (B) subjects over $N = 30$ trials each. To estimate the start point of a gaze bias, we used a significance threshold method (see Section 4). The "cascade" start point was defined as the time when the curve passed this threshold and never returned at or below it.

As predicted by our claim that orienting contributes to preference decision making, a "gaze cascade effect" occurs in the preference task. While the magnitude (maximum height 84%) is comparable with the ones in the full-stimulus tasks (approx. 85%; Shimojo & Simion et al., 2003), the duration of the effect stands out when a gaze-contingent window is used. The curve starts to significantly depart from the 50% zone with around 7.5 s before decision, much earlier than the 800–1200 ms we computed in our original study. In contrast, in the roundness task the gaze bias starts less than 1 s before decision and its amplitude is significantly smaller (75%). The Kolmogorov–Smirnov test confirmed that the two curves are significantly different ($d_{KS} = 2.89$, $p < 0.0001$).

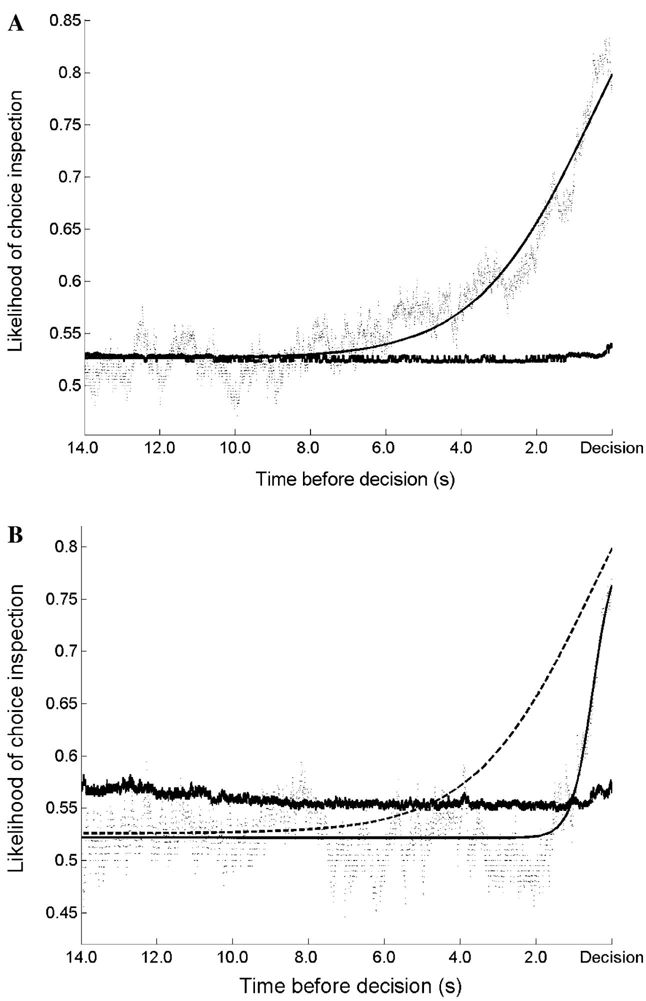

Fig. 2. The likelihood that observers' gaze was directed towards the eventual choice is plotted against time before decision, in the attractiveness (A) and roundness (B) tasks. The last 14 s of each trial were analyzed. The solid lines represent the 4-parameter sigmoid fits of the raw-data (dots). The sigmoid fit from (A) is replotted in B (dashed line) for comparison. The corresponding significance thresholds for each task are also plotted, and are variable because of changes in sample size due to blinks, saccades or trials shorter than 14 s.

3. Discussion

The main result of this paper is that a gaze cascade effect accompanies preference, but not control decision making in the gaze-contingent "peephole" experiment. It is notable that the entire effect was elongated in time domain, with its onset more than 7 s before decision. If we assume, as in Shimojo and Simion et al. (2003), that the cascade effect is the illustration of an interaction between orienting and preference decision making, this study shows that such interactions can arise relatively early in the information processing stream and strengthens our claim that orienting is a intrinsic component in the process of choosing preference.

Additionally, a few alternative explanations for this effect are rebutted in this study. First, the selection bias account, proposing that subjects tend to dwell on the (already chosen) stimulus for the last fixation, is invalidated by the difference in the onset of gaze cascade (7.4 s vs. 0.8 s) between the preference and the control tasks. Such an account would predict a gaze bias of relatively short duration and locked to the point of decision regardless of task. The result obtained in the preference task is way too long. Second, the necessity of a holistic matching of the visual display with an internal representation template for the gaze bias to occur is eliminated. Since holistic matching is not available at any point during the experiments reported here, this setup emphasizes the decoupling between orienting and the presence of visual stimulation. Third, there is a possibility that an "internal decision" is made before the start of the gaze bias, which only reflects further sampling of "evidence" for reconfirmation. To be consistent with our results, the reconfirmation account must assume that the roundness control needs minimal to no reconfirmation, while the attractiveness task needs 6–7 s, being a more difficult task. Instead of trying to discount such interpretation, we remind the reader that our claim is that orienting is intrinsically involved in the entire process leading to the final conscious preference choice, which may include "recruiting additional evidence". Even in that case, the reconfirmation account may encounter a hard challenge in establishing the exact moment of the internal decision, which is beyond the point of this investigation.

Overall, our results add to earlier evidence that choosing what we like is unique relative to other tasks in its intrinsic dependency on orienting. The process of making an overt preference choice is accompanied by the preceding gaze cascade effect even when orienting is mainly internally driven.

The lack of global information makes inspection through a small gaze-contingent window very difficult, especially with faces, traditionally known as holistic stimuli. Our "peephole" method is in some ways similar to Bubbles (Gosselin & Schyns, 2001), in that it drastically limits the amount of visual information that observers have available at any point in time. While Bubbles is very successful at determining what stimulus features are important for various perception tasks (e.g., face perception, Smith & Cottrell et al., 2005), the peephole setup enables finer temporal control over what can be perceived. It effectively acts as a temporal zoom lens allowing us to reveal through psychophysics the time course of the interactions between orienting, visual processing and decision making. Similar to the authors of Bubbles, we take as given that internal representations, short-term memory and task-specific intentions, rather than stimulus visual features, play a crucial role in the completion of the tasks presented herein. Nevertheless the gaze bias, reinforced through positive feedback, drives the preference decision to completion in the same manner as it did in the previous, full-stimulus tasks.

It is in particular noteworthy that our subjects could have done the preference task the same way as the roundness task (i.e., spatial and sensory sampling first, then decision), but they did not. Instead, while the brain was still recruiting local information across fixations, the gaze cascade had already started and was developing, showing that the orienting bias overlaps temporally with the visual sampling. Based on the qualitative similarity of the gaze bias dynamics, except for the onset timing, we speculate that essentially the same interaction happens in the ordinary observation conditions, but the short decision times make its illustration more difficult. The results presented herein form in our view stronger evidence that the gaze is *intrinsically involved* in preference decision making.

In cognitive and psychological domains, our findings are in good affinity with the view of "self" as an other (Bem, 1967), as well as with the somatic marker hypothesis (Bechara & Damasio et al., 2000; Damasio, 1996). Common among them is the general claim that one often needs to observe and to cognitively interpret one's own behavior in order to generate emotion, which in turn affects judgment. As for more general implications, the present work puts orienting in the category of active, self-sustaining behaviors, which can be incorporated in more complex and dynamic processes and separates it from the presence of attention grabbers in the environment. Our results also supports recent, parallel and dynamic models of the brain, in which sensory experience and higher-level brain functions such as emotional valence or decision making share fast reciprocal connections, continually influencing each other from very early on in the perceptual processing.

4. Experimental procedures

Pairs of images of human faces were placed on a CRT computer screen. The images were 480×480 pixel JPEG files, subtending 16×16 degrees of visual field, and were located on the horizontal midline of the computer screen and of the observers' field of view, and at equal distance left and right from the vertical midline. A blank screen was initially covering the images, with square frames clearly indicating the location of the face images underneath.

Using the on-line eye-tracking capability of EyeLink2© (SR Research, www.eyelinkinfo.com), we created a gaze-contingent setup in which observers were revealed the portion of the underlying display that they chose to foveate. A small, circular 75 pixel diameter (2.5 degrees of visual angle) gaze-contingent window was visible at any given time. The very short delay of the Eyelink2© system (<3 ms) in transmitting data from the eye-tracking software back into the experimental setup ensured the contingency of whatever could be viewed to the observers' foveal vision.

Eleven naïve, healthy observers (Caltech undergraduate and graduate students) were run in this experiment after their written consent was obtained. They were paid $5 for the experiment. The task was to inspect both faces hidden under the blank screen and decide which one was more attractive ($N = 7$, attractiveness task) or rounder ($N = 4$, roundness task). The response was recorded with a corresponding button press for either the left or the right face. As mentioned, the observers could never see more than a circular 2.5 degree portion of the face image at any time, ensuring that only piecemeal perception of the stimuli could occur.

Eye-movements were tracked with the EyeLink2© system at 500 MHz, pupil reflection mode. Head movements were compensated for and we performed calibration before the experiment, as well as drift correction prior to each trial. Each experimental condition consisted of $N = 30$ trials. Eye movement data analysis was performed and the likelihood curve was computed as described in Shimojo and Simion et al., 2003. Since the data points contained in the likelihood curves were averages over binary values (0 and 1), we determined, for each sampling point t, the maximum probability value at which a coin would be considered fair with 95 percent confidence, given a number of tosses equal to the number of trials averaged at that sampling point. We called this the "significance threshold". The cascade effect was defined as that increasing part of the likelihood curve that irreversibly rose above this threshold. The time at which the bias started and the maximum likelihood just prior to the button press were considered significant parameters for comparing the effect in the two present conditions, as well as in our past experiments.

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References

Adolphs, R., Gosselin, F., et al. (2005). A mechanism for impaired fear recognition after amygdala damage. *Nature, 433*(7021), 68–72.

Bechara, A., Damasio, H., et al. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex, 10*(3), 295–307.

Bem, D. J. (1967). Self-perception—an alternative interpretation of cognitive dissonance phenomena. *Psychological Review, 74*(3), 183.

Bertera, J. H., & Rayner, K. (2000). Eye movements and the span of the effective stimulus in visual search. *Perception & Psychophysics, 62*(3), 576–585.

Corkin, S. (2002). What's new with the amnesic patient HM? *Nature Reviews Neuroscience, 3*(2), 153–160.

Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philosophical Transactions Of The*

Royal Society Of London Series B-Biological Sciences, 351(1346), 1413–1420.

Emery, N. J. (2000). The eyes have it: the neuroethology, function and evolution of social gaze. *Neuroscience And Biobehavioral Reviews, 24*(6), 581–604.

Fantz, R. L. (1964). Visual experience in infants—decreased attention to familiar patterns relative to novel ones. *Science, 146*(364), 668.

Fellows, L. K., & Farah, M. J. (2005). Different underlying impairments in decision-making following ventromedial and dorsolateral frontal lobe damage in humans. *Cerebral Cortex, 15*(1), 58–63.

Gosselin, F., & Schyns, P. G. (2001). Bubbles: a technique to reveal the use of information in recognition tasks. *Vision Research, 41*(17), 2261–2271.

Hauser, M. D., Agnetta, B., et al. (1998). Orienting asymmetries in rhesus monkeys: the effect of time-domain changes on acoustic perception. *Animal Behaviour, 56*, 41–47.

Kleinke, C. L. (1986). Gaze and eye contact—a research review. *Psychological Bulletin, 100*(1), 78–100.

Kunstwilson, W. R., & Zajonc, R. B. (1980). Affective discrimination of stimuli that cannot be recognized. *Science, 207*(4430), 557–558.

McConkie, G. W., & Rayner, K. (1975). Span of effective stimulus during a fixation in reading. *Perception & Psychophysics, 17*(6), 578–586.

Pomplun, M., Reingold, E. M., et al. (2001). Peripheral and parafoveal cueing and masking effects on saccadic selectivity in a gaze-contingent window paradigm. *Vision Research, 41*(21), 2757–2769.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*(3), 372–422.

Saida, S., & Ikeda, M. (1979). Useful visual-field size for pattern perception. *Perception & Psychophysics, 25*(2), 119–125.

Schall, J. D. (2001). Neural basis of deciding, choosing and acting. *Nature Reviews Neuroscience, 2*(1), 33–42.

Shimojo, S., Simion, C., et al. (2003). Gaze bias both reflects and influences preference. *Nature Neuroscience, 6*(12), 1317–1322.

Shipp, S. (2004). The brain circuitry of attention. *Trends In Cognitive Sciences, 8*(5), 223–230.

Sigala, N., & Logothetis, N. K. (2002). Visual categorization shapes feature selectivity in the primate temporal cortex. *Nature, 415*(6869), 318–320.

Smith, M. L., Cottrell, G. W., et al. (2005). Transmitting and decoding facial expressions. *Psychological Science, 16*(3), 184–189.

Sokolov, E. N. (1963). Higher nervous functions—orienting reflex. *Annual Review Of Physiology, 25*, 545.

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal Of Personality And Social Psychology, 9*(2P2), 1.